Montana Knapweeds:

Identification, Biology and Management

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Montana Knapweeds: Identification, Biology, and Management

by Celestine Duncan, Jim Story and Roger Sheley*

Knapweed can infest cultivated hay lands, and seed can be transported in hay to infest new areas. Photo by Celestine Duncan

Spotted knapweed (*Centaurea maculosa*), diffuse knapweed (*Centaurea diffusa*), squarrose knapweed (*Centaurea virgata*), yellow starthistle (*Centaurea solstitalis*) and Russian knapweed (*Acroptilon repens*) are closely related noxious weeds that have invaded Montana. These weeds are well adapted to a wide range of habitats including open forests, rangeland, roadsides, CRP lands, pastureland and ditch banks. Russian knapweed can also infest cultivated crop and hay land.

The knapweeds and starthistle threaten long-term productivity of Montana grazing lands and wildlands by reducing biodiversity and increasing soil erosion. These aggressive weeds displace native species, change plant community structure, degrade or eliminate habitat for native animals, reduce forage for livestock and wildlife, and provide food and cover for undesirable non-native animals. The economic impact to agriculture and wildlands from these weeds is substantial. The potential annual loss to Montana's economy from spotted knapweed alone is estimated to be $42 million. If knapweed continues to invade highly vulnerable lands, the potential annual loss to Montana's

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livestock industry would be $155 million each year.

The purpose of this publication is to provide information about identification, biology and management of knapweeds in Montana and surrounding states. It also provides information necessary for developing and implementing integrated management strategies for these serious invasive weeds.

Knapweeds infest natural areas, impacting wildife habitat, displacing native species and changing plant community structure. (Photo by C. Duncan)

IDENTIFICATION AND BIOLOGY

Spotted knapweed

Spotted knapweed is a tap-rooted perennial forb that spreads by seed. Seedlings usually over-winter in a rosette stage and resume growth in early April. The rosettes are easy to recognize because leaf margins are indented or divided about halfway to the mid-rib. Most stem growth occurs in June. Stem height varies from two feet on upland range sites to as much as four feet on sites receiving additional moisture. The slender stems are many-branched and have a single flower at the tip of each branch. Flower color is usually pinkish-purple, but can also be light purple or white. Each flower head has bracts located under flower petals that are marked with fine vertical streaks and tipped with a dark comb-like fringe. These bracts give a “spotted” appearance to the flower head.

Spotted knapweed blooms from mid- to late July through early September. Individual flower heads bloom for two to six days before the bracts close. Bracts reopen after about 20 days, and seeds are dispersed by physical movement of the plant. The weed is a prolific seed producer with 1000 or more seeds per plant. Seeds remain viable in soil for more than eight years and are spread easily by water, animals, humans and vehicles.

Spotted knapweed can be identified by the black-tipped bracts on the flower head. Flower color is usually pink to purple but can also be white. (photo by Steve Dewey, Utah State University)

Diffuse Knapweed

Diffuse knapweed is a tap-rooted annual, biennial or short-lived perennial forb that reproduces by seed. Plants overwinter as a rosette that resembles spotted knapweed. Plants usually produce a single main stem that divides into numerous branches about halfway up the stem, giving it a ball-shaped, tumbleweed appearance and mobility. A single flower head is at the end of each branch. Flowers are usually white, but can range to light purple. Bloom period is usually from mid-July through September. Bracts on diffuse knapweed have a rigid terminal spine about one-quarter to one-third of an inch long with four to five pairs of shorter lateral spines. Bracts can have dark-colored tips but lack the dark fringe present on spotted knapweed.

Diffuse knapweed is distinguished from spotted knapweed by spine-tipped bracts on the flower head. Flower color is usually white, but can range from white to light purple. (photo by Steve Dewey, USU)

Diffuse knapweed spreads mainly by wind. Mature plants break off at ground level and tumble in the wind or become attached to the undercarriage of vehicles and equipment.

Squarrose Knapweed

Squarrose knapweed is a long-lived perennial forb that reproduces by seed. Rosette leaves are similar to those of spotted and diffuse knapweed but may wither when the plant flowers. Stems are highly branched and tipped with relatively small rose or light pink colored flowers. Bracts on squarrose knapweed are recurved or spreading, with the terminal spine longer than lateral spines on each bract. The plant blooms from late June through August. At seed maturity, heads remain closed, but stems weaken, which causes the head to drop easily from the plant. The recurved bracts enable heads to cling like burs to hair, wool, clothing or vehicles, allowing them to be spread easily. Not all heads fall from the plant, and those remaining greatly extend the seed distribution period.

Squarrose knapweed is distinguished from the other knapweeds by recurved or spreading bracts on the flower head. Flower color is rose or light pink. (photo by Steve Dewey, USU)

Yellow Starthistle

Yellow starthistle has yellow-green spines on the ends of bracts that can be from one-quarter inch to two inches long when the flower is fully open. Flower color is yellow. (photo by Steve Dewey, USU)

Yellow starthistle is a tap-rooted, winter-hardy annual that normally germinates from seed in the fall. Plants overwinter as a small rosette, and in early June begin to produce a flower stem. The stem may be unbranched or have many branches, each tipped with a single yellow flower. The flowering period is from late June through August. Bracts on yellow starthistle have a yellow-green spine that can be from one-quarter inch to two inches long when the flower is fully open. Plants mature at heights from three inches up to four feet. Yellow starthistle can produce several thousand seeds per plant. Seed remain viable for as long as ten years and are easily spread by wind, water, animals, humans and vehicles.

The weed causes a neurological disorder in horses called "chewing disease," since affected animals are unable to eat or drink. Affected horses may never recover.

Russian Knapweed

Russian knapweed is a deep-rooted, rhizomatous, perennial forb that grows about two feet tall. The weed spreads both by seed and underground roots. Stems are thin, stiff and covered with soft short hairs. Rosette leaves are narrow at the base and widen toward the tip. Flower color is light pink to purple.

Russian knapweed bracts are egg-shaped, light green at the base, and have a papery tip. Flower color is light purple. (photo by Steve Dewey, USU)

Three characteristics distinguish Russian knapweed from the other knapweeds discussed in this publication:

1) Flower head bracts of Russian knapweed have light thin hairs, a papery tip and are green at the base;

2) Russian knapweed spreads by deep, scaly, creeping rhizomes (the dark-colored roots can grow to depths of eight feet the first year and to 23 feet during the second growing season); and

3) Russian knapweed is not a prolific seed producer. Russian knapweed causes the same neurological disease in horses as yellow starthistle. Poisoning by knapweeds and yellow starthistle is generally associated with a lack of good quality forage in infested pastures.

ORIGINS AND DISTRIBUTION

Spotted and diffuse knapweed are native to grassland steppes of eastern Europe and Asia Minor. The native range of spotted knapweed is central Europe and east to central Russia, Caucasia and western Siberia. Diffuse knapweed grows in the eastern Mediterranean area, in western Asia and from the southern part of former USSR to western Germany. Both spotted and diffuse knapweed were introduced to North America from Eurasia as contaminants in alfalfa. Spotted knapweed was also introduced through discarded soil used as ship ballast. Spotted knapweed was first recorded in the Northwest in Victoria, British Columbia in 1883, and in Ravalli County, Montana in 1920. By 1991, the weed had been recorded in every county in Montana. It is the most widespread knapweed in the state, infesting from two to five million acres. An estimated 34 million acres are highly susceptible to invasion by this weed

Diffuse knapweed was first recorded in North America in Washington in 1907 and in Mineral County, Montana in 1951. Presently 40 counties have reported diffuse knapweed infestations, totaling about 12,000 acres in the state.

Squarrose knapweed is native to southwest Asia and the Middle East. The weed was first recorded in northern California in 1950 and in Juab County, Utah in 1954. Unofficial records indicate that the weed was present in Utah as early as 1928, where it currently infests an estimated 100,000 acres in five counties. In the Northwest, the weed was first reported in 1988 in Oregon, 1998 in Wyoming, and in 2000 in Judith Basin County, Montana. All known infestations in Montana have been eradicated.

Yellow starthistle is native to dry open habitats in southern Europe. It was first introduced into the United States in Oakland, California in the 1850s as a contaminant of ballast soil or alfalfa seed. Since that time, it has spread to infest from 12 to 20 million acres in California and is a major rangeland weed in Oregon, Washington and Idaho. The weed was first reported in Ravalli County, Montana in 1958. Since that date, yellow starthistle has been reported in Gallatin, Lake, Flathead, Carbon, Sweetgrass and Ravalli Counties. All known infestations in Montana have been eradicated.

Knapweeds pose a long-term threat to productivity of Montana's rangeland. (photo by C.Duncan)

Russian knapweed is native to Mongolia, Russian Turkestan, Iran, Turkish Armenia and

Asia Minor. Seeds of Russian knapweed were present in alfalfa seed imported from Russian Turkestan beginning in 1898 and 1899. An estimated 500,000 acres were planted with commercial Turkestan alfalfa in the United States. Once imported, it spread widely by sale of domestically produced alfalfa seed or hay containing weed seeds. It was first reported in the Northwest in Yakima County, Washington in 1922 and in Fergus County, Montana in 1934. By 1991, the weed was recorded in every county in Montana and infests an estimated 51,000 acres.

INTEGRATED MANAGEMENT TECHNIQUES

Successful management of large-scale knapweed infestations requires integrating several weed management methods in a well-planned, coordinated and ecologically based approach. The goal of a management program should be to develop healthy plant communities that are weed-resistant and meet other land-use objectives such as livestock forage, wildlife habitat or recreation.

Inventory, monitoring and public education are vital components of an integrated weed management program. However, this publication limits discussion to prevention and control techniques.

Prevention

Early detection and treatment is the key to preventing the spread of knapweeds and starthistle onto non-infested range and pasture sites. People and their motorized vehicles are a major cause of knapweed spread in Montana. Vehicles driven several feet through a knapweed site can acquire up to 2000 seeds, 200 of which may still be attached after 10 miles of driving. It is imperative to wash the undercarriage of vehicles that have been in weed-infested areas. Dispersal of weed seeds can be minimized by not driving, walking or trailing livestock through weed-infested areas. Only certified weed-seed free seed and hay should be purchased. Livestock should not be grazed in knapweed-infested sites during flowering and seeding, and livestock should be held for seven days before moving to uninfested pastures.

Knapweed seed can be spread by vehicles and also transported by movement of gravel and other fill material. (Photo by C. Duncan)

Herbicides

Selective herbicides provide good control of the knapweeds and starthistle, and are often the most cost-effective treatment for small or new infestations. Herbicide treatments on large infestations are most effective when combined with other management methods that enhance the

competitive ability of desirable forage species. The most effective herbicides for controlling knapweeds are picloram (Tordon 22K[1]); clopyralid (Transline[1]); clopyralid plus 2,4-D (Curtail[1]); clopyralid plus triclopyr (Redeem[1]); dicamba (Banvel[2]); and 2,4-D.

Each herbicide has special characteristics that makes it useful in specific situations. The "amine" formulation of 2,4-D can be applied along rivers and riparian areas but provides the most inconsistent control of these herbicides. Both picloram and clopyralid tend to stay in the upper portion of the soil horizon and provide effective long-term control of knapweeds on upland sites.

Herbicides are an important component of an integrated knapweed management program. Yellow starthistle on the right side of the photo was treated with Transline at 1 pint per acre. (Photo by C. Duncan)

[1]Trademark of Dow AgroSciences LLC [2]Trademark of BASF

Spotted, diffuse, and squarrose knapweed and yellow starthistle

Tordon 22K applied at rates of 0.25 pounds active ingredient (ai) per acre (1 pint) provides from two to seven years of control depending on site conditions, and is the most

Figure 1. Percent control of spotted knapweed two years after treatment (2 YAT) with Banvel, Curtail and Tordon 22K applied at five different application times.

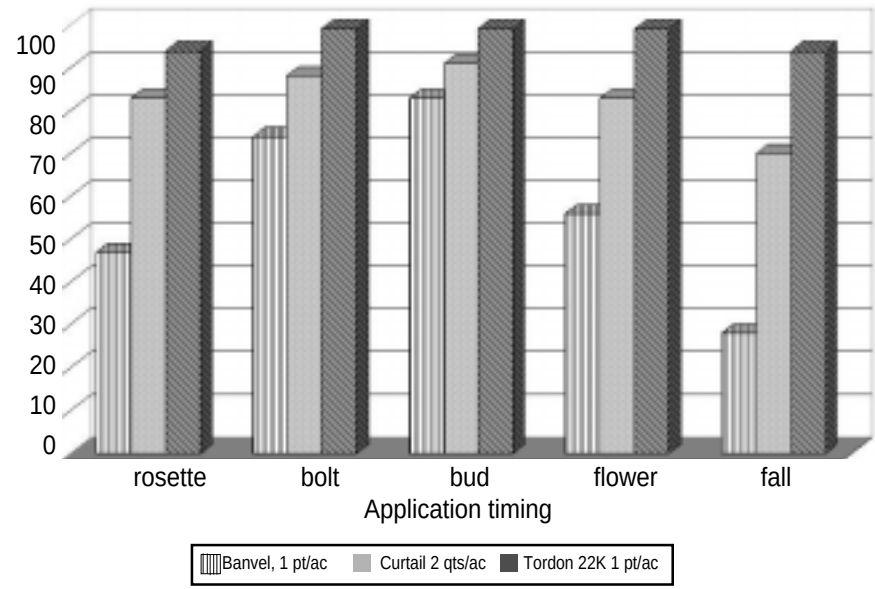

TABLE 1. COST AND EFFECTIVENESS OF VARIOUS TREATMENTS FOR CONTROLLING SPOTTED KNAPWEED (BROWN ET.AL. 1999)

Treatment	Rate per acre and number of times applied	Plant Growth Stage	Application Date		Plant Control two years after treatment	Cost /Acre[1] two years after treatment
			Year 1	Year 2		
			Month/day	Month/Day	%	Cost
Hand-pull (bolted plants)	2 times /year	Early and late bud	6/20 7/20	6/20 7/22	25	$13,900.00
Tordon 22K + Hand-pull	1/2 pint, 1 time	Bolt (spray) Late bud (pull)	6/2 -----	----- 7/21	94	$97.90
Mowing alone	2 times/year	Early and late bud	6/20 7/20	6/19 7/17	0[2]	$200.00
Mowing + Curtail	1 time mowing; 1 quart sprayed 1 time	Late bud (mow) Fall regrowth (spray)	7/16 9/29	----- -----	91	$77.67
Curtail	1 quart, 1 time	Fall regrowth	9/29	-----	68	$27.67
Tordon 22K (standard)	1 pint, 1 time	Bolt	6/2	-----	95	$30.75
Curtail	2 quarts, 1 time	Bolt	6/2	----	89	$35.37

[1] Costs based on the following information: Hand pulling – wages $9/hour; mowing - $50/acre; Tordon 22K - $86/gallon; Curtail - $30.70/gallon; ground application - $20/acre.

[2] Data from Rinella et.al., shows an average of 52% control after mowing in the fall for three consecutive years.

cost-effective herbicide treatment. Control tends to be shorter in duration on coarse-textured soils and on sites with an annual rather than perennial grass understory. Timing of application with Tordon 22K is not critical for controlling spotted or diffuse knapweed (Figure 1), but applications must be made prior to late bud growth stage to stop or reduce seed production that year. Since yellow starthistle is an annual, applications should be made no later than bud stage. Tordon 22K applied at 0.125 lbs a.i. per acre (1/2 pint) can be combined with hand pulling to extend the effectiveness of the herbicide application (Table 1).

Transline at 0.25 lbs a.i. per acre (2/3 pint) or Curtail at 1.19 lbs a.i. per acre (2 quarts) provide good to excellent spotted knapweed control for one to three years when applied during bolt or bud growth stages. Control with Curtail declines to less than 83 percent when applied at rosette, flower and after-flowering growth stages (Figure 1). Curtail and Transline applied at these rates will remove knapweed from the plant community with limited impact on non-target broadleaf plants. Redeem at 0.56 to 0.75 lbs a.i. per acre (1.5 to 2 pints) provides good control of spotted knapweed.

Banvel applied alone at 1 lb a.i. per acre (1 quart) and 2,4-D at 2 lbs a.i. per acre (2 quarts) provides inconsistent control of the knapweeds. Banvel at 0.5 lbs a.i. per acre (1 pint) in combination with 2,4-D at 1 lb a.i. per acre (1 quart) provides control similar to that of Curtail when applied at the bud growth stage (Figure 1). Applications of 2,4-D alone must be made annually at the rosette to mid-bolt growth stage, until no viable seed remain in the soil.

Russian knapweed

The extensive root system of Russian knapweed makes it more difficult to control than the other knapweeds or yellow starthistle. Tordon 22K at 0.5 to 0.75 lbs a.i. acre (1 to 1.5 quarts), Curtail at 1.8 lbs a.i. per acre (3 quarts) or Transline at 0.375 to 0.5 lbs a.i. acre (1 to 1.3 pints) should be applied to Russian knapweed at the late bud to early bloom growth stages or in the fall following a light frost. The lower recommended herbicide rate can be applied in the fall of the year. Applications of Transline and Curtail made prior to the bud growth stage will be inconsistent. Banvel at 2 lbs a.i. per acre (2 quarts) alone and in combination with 2,4-D provide inconsistent control of Russian knapweed at all growth stages.

Biological Control

Biological weed control is the deliberate use of natural enemies (parasites, predators or pathogens) to reduce weed densities to acceptable levels. These natural enemies have been extensively tested to ensure that they will not attack non-target plants. Biological control is attractive because it is biologically based, self-perpetuating, selective, energy self-sufficient and economical. However, biocontrol is not without limitations. Biocontrol is a very slow process, does not achieve eradication, is often too selective, may be ineffective without being integrated with other strategies, and may not be appropriate against weeds that are closely related to beneficial plants because the natural enemy may be unable to discriminate between related plant species.

Biological control will play an important role in the ultimate management of most of the knapweeds. However, as mentioned, biocontrol does have limitations and, therefore, will not be a "cure-all." Successful management of the knapweeds will be a long-term effort involving the combined use of *all* available control methods and improved land management practices in an integrated approach.

Spotted and diffuse knapweed

Thirteen Eurasian natural enemies (all insects) have been introduced into Montana for biological control of spotted and diffuse knapweed (Table 2). Most of the insects attack both plant species. Status of insects in Montana follows:

Two flower head flies (*Urophora affinis* and *U. quadrifasciata*) were introduced into Montana in 1973 and 1980, respectively, and are now well established in the state. The larvae induce galls in flower heads, which reduces seed production. Seed reductions in excess of 50 percent are occurring in areas where the two fly species coexist.

A flower head moth (*Metzneria paucipunctella*), released in 1980, is established in small numbers in western Montana. The larvae feed on the florets and seeds of spotted knapweed. Each larva destroys about eight seeds per flower head.

A root moth (*Agapeta zoegana)* and a root weevil (*Cyphocleonus achates),* released in 1984 and 1988, respectively, are both established at numerous locations in Montana. Larvae of the moth girdle knapweed roots, while the weevil larvae feed in the center of roots. The two insects are causing measurable reductions in knapweed biomass at several locations. Both insects are being mass-reared at the Western Agricultural Research Center at Corvallis, Montana to hasten their distribution throughout knapweed-infested areas of the state.

A root beetle (*Sphenoptera jugoslavica*), released in 1983, is established on diffuse knapweed in several areas, especially near East Helena, Montana. The larvae feed in the center of the root. The beetle primarily attacks roots of diffuse knapweed, but will also attack spotted knapweed. The insect appears to be causing reductions in diffuse knapweed biomass in selected areas.

Two flower head weevils (*Larinus minutus* and *L. obtusus)* were released in Montana in 1991 and 1992, respectively. *Larinus minutus,* released against diffuse knapweed, is well established at several locations in Montana, and is causing significant reductions in the biomass and density of that plant near East Helena. *Larinus obtusus,* released against spotted knapweed, is established but is increasing at a much slower rate than *L. minutus*. The larvae of both weevils feed on knapweed seeds, and the adults feed on knapweed leaves.

Three insects, a root moth (*Pelochrista medullana*) released in 1984, and two seed head flies (*Chaetorellia acrolophi* and *Terellia virens*) released in 1992, are established on spotted knapweed, but in very small numbers. The life history and behavior of *P. medullana* is very similar to *A. zoegana*, but for unknown reasons, *P. medullana* has had great difficulty establishing in Montana. Similarly, *C. acrolophi* and *T. virens* are not establishing nearly as easily as the seed head gall flies (*Urophora* spp.) In contrast to the *Urophora* species, the larvae of *C. acrolophi* and *T. virens* feed directly on the seeds and do not form galls.

TABLE 2. STATUS OF INSECTS RELEASED IN MONTANA AGAINST SPOTTED, DIFFUSE AND RUSSIAN KNAPWEED.

Scientific Name	Insect Type	Plant Part Attacked	Date Released	Status
Spotted and diffuse knapweed				
Urophora affinis	Fly	Flower head	1973	Established[1]
Urophora quadrifasciata	Fly	Flower head	1980	Established[1]
Metzneria paucipunctella	Moth	Flower head	1980	Established[2]
Agapeta zoegana	Moth	Root	1984	Established[1]
Cyphocleonus achates	Weevil	Root	1988	Established[1]
Pterolonche inspersa	Moth	Root	1988	Not established
Pelochrista medullana	Moth	Root	1984	Established[3]
Bangasternus fausti	Weevil	Flower head	1992	Not established
Larinus obtusus	Weevil	Flower head	1992	Established[2]
Larinus minutus	Weevil	Flower head	1991	Established[2]
Terellia virens	Fly	Flower head	1992	Established[3]
Chaetorellia acrolophi	Fly	Flower head	1992	Established[3]
Sphenoptera jugoslavica	Beetle	Root	1983	Established[2]
Russian knapweed				
Mesoanguina picridis	nematode	root		Established[3]

1 - widely established, or established in moderate numbers at numerous sites
2 - established in moderate numbers at several sites
3 - established in very small numbers

Two insects, a root moth (*Pterolonche inspersa*) and a flower head weevil (*Bangasternus fausti*) have failed to establish on spotted knapweed in Montana, following their release in 1988 and 1992, respectively.

Squarrose knapweed

Squarrose knapweed is closely related to spotted knapweed, so many of the insects released against spotted and diffuse knapweed have been successfully established on squarrose knapweed in states where the plant is common (California, Oregon and Utah). Insects established on the plant in these states include *A. zoegana*, *B. fausti*, *C. achates*, *L. minutus*, *S. jugoslavica*, *U. affinis* and *U. quadrifasciata*. Biocontrol is not a control option in Montana due to the scarcity of the plant.

Yellow starthistle

Biological control has been implemented against yellow starthistle in other states where the plant is widespread (California, Idaho, Oregon and Washington). Five insects have been introduced against the plant. These include three seed head weevils (*Bangasternus orientalis*, *Eustenopus villosus* and *Larinus curtus*) and two seed head flies (*Urophora sirunaseva* and *Chaetorellia australis*). Biological control is not a control option in Montana due to scarcity of the plant

Russian knapweed

Only one biocontrol agent, a nematode (*Mesoanguina picridis*), has been released against Russian knapweed in Montana. The nematode is established at several sites but it has not been effective. Six Eurasian natural enemy species are being screened as potential biocontrol agents.

Burning

A single, low-intensity fire does not control knapweed or starthistle. In fact, it may increase cover and density of spotted, squarrose and diffuse knapweed. This type of burn creates open areas or "niches," which promote establishment and spread of the knapweeds. Fire followed by herbicide treatments may increase effectiveness of herbicide treatments on knapweed. Although a single burning event will not control knapweed, planned sequential burning of yellow starthistle sites in northern California have resulted in a reduction of yellow starthistle and increase in perennial native species.

Cultivation

Cultivation to depths of seven inches or more will control yellow starthistle and spotted, diffuse and squarrose knapweed. However, even under intensive cultivation, these weeds can regenerate from seeds remaining in soil. Cultivation will increase rate of spread and establishment of Russian knapweed since root sections broken during cultivation will form new plants. Cultivation, in combination with reseeding competitive perennial grasses, may minimize reinvasion of the knapweeds.

Grazing

Controlled repeated grazing with sheep can reduce the number of spotted knapweed plants.
(Photo by Dr. John Lacey, MSU, retired)

Cattle, sheep and goats will graze spotted knapweed at low to moderate levels. Although rosettes of first year knapweed plants are nutritious and edible, they are difficult for cattle to eat because they grow close to the ground. Mature spotted knapweed plants are fibrous and coarse, which make them less desirable. Controlled, repeated grazing of spotted knapweed by sheep can reduce the number of one- and two-year-old spotted knapweed plants within an infestation. Grazing must be timed so that associated grasses are dormant to limit impact on desirable species. Knapweed can be grazed in early spring before native desired species initiate growth, again during the growing season, and finally during late fall when desired species are dormant. When grazing during the growing season, do not allow sheep or goats to graze over 20 percent of the desired species. This will allow desirable vegetation to remain vigorous and productive.

Combining herbicides with sheep grazing can also be very effective for controlling some knapweeds. The herbicides can be used to control mature unpalatable plants, and sheep will selectively remove knapweed plants as they re-emerge. As with any strategy, grazing with sheep or goats must be a continuous effort.

Under a short-duration grazing strategy with cattle, spotted knapweed seedlings and rosettes decreased, but bare ground increased and litter decreased. Any procedures that increase bare gound on rangeland are not recommended.

Handpulling

Persistent and careful hand pulling can control yellow starthistle and spotted, diffuse and squarrose knapweed. Since regrowth can occur from both crowns and viable seed in the soil, the entire crown portion of the plant must be removed before the plant produces seed. Plants can be pulled most effectively following a rain or when the soil is moist. Flowering plants must be contained and removed from the site and disposed of in a manner ensuring seeds are not dispersed. Disturbance caused by hand pulling may increase susceptibility of the site to reinvasion by weeds. While this control method is effective on single plants or relatively small infestations, it is not economically or physically feasible on large, well-established knapweed infestations (Table 1).

Handpulling is not an effective treatment for Russian knapweed because the plant rapidly resprouts from rhizomes.

Mowing

There has been limited research on long-term effects of mowing on the knapweeds and yellow starthistle. The effectiveness of mowing yellow starthistle depends on proper timing and plant growth form. Erect, high-branching yellow starthistle plants can be effectively controlled by a single mowing at early flowering, while low-branching plants are not satisfactorily controlled by multiple mowing. Mowing yellow starthistle prior to late bud growth stage increases amount of seed produced. A single mowing at late bud growth stage can reduce the number of seed produced on spotted knapweed.

In one study, fall mowing of spotted knapweed for three consecutive years reduced adult plant density an average of 73 and 41 percent at two locations. Seedling density may also be reduced by mowing treatments. Another study indicated that spotted knapweed mowed at bolt and late bud stage for two consecutive years did not reduce spotted knapweed cover (Table 1). Mowing at the late bud stage in combination with Curtail at 1 quart per acre provided better control than a similar rate of Curtail applied alone. Mowing prior to a Tordon application did not improve knapweed control compared to the herbicide treatment alone (Table 1).

Revegetation

A weed-resistant plant community is comprised of diverse species that occupy most of the niches. In areas where desirable native plant species are absent, long-term control of knapweed or starthistle is unlikely, because desirable species are not available to occupy niches opened by control. Establishing competitive plants is essential for successfully managing the knapweeds and starthistles and restoring plant communities. Revegetation with aggressive desirable species has been shown to inhibit reinvasion of knapweeds.

Revegetation of knapweed-infested rangeland usually involves a spring or early summer application of Tordon 22K, Transline or Curtail followed by a dormant seeding of grass in late fall. If the site can be cultivated, spring treatments with herbicides are not necessary with spotted and diffuse knapweed and yellow starthistle. Both grass and knapweed seedlings will emerge the following spring as long as there is adequate moisture for germination. Knapweed seedlings can be controlled with reduced rates of 2,4-D, Transline, Redeem or Curtail. Selection of species most effective for revegetation of knapweed infested rangeland will depend on site conditions including soil type, moisture, slope and aspect.

In order to make revegetation more cost-effective, a one-pass system can also be used. In this case, Tordon 22K is applied during late fall simultaneously with seeding using a no-till drill. This must be conducted late enough in the fall to ensure no seeds germinate before winter. For spotted knapweed infestations in areas ranging from 13 to 18 inches of annual precipitation in Montana, “Luna” pubescent wheatgrass and bluebunch wheatgrass established well and have kept weeds from reinvading for about six years.

Proper Grazing Management

Proper grazing management is essential to maintaining competitive desired plants, which slow knapweed encroachment. To minimize weed invasion, grazing systems should alter the season of use, rotate or combine livestock types and pastures to allow grazed plants to recover before being regrazed, and promote litter accumulation. Desirable species must fully recover from the prior grazing before being regrazed. On knapweed-infested rangelands, herbicide treatments should be combined with implementation of a grazing system to reduce knapweed density.

SUMMARY

Implementing a successful integrated weed management program requires preventing knapweeds and starthistle from spreading, detecting and eradicating new infestations, containing large infestations and combining strategies to favor desired plants. The success of a knapweed management program requires long-term commitment and cooperation between private land owners, public land users and government agencies.

Preventing weed seed spread onto adjacent rangeland is the most cost-effective management strategy. Each of us must reduce or eliminate knapweed and starthistle seed dispersal by:

- Not driving motorized vehicles through knapweed or starthistle infestations.
- Purchasing and transporting only certified noxious weed seed free hay and forage.
- Minimizing soil disturbance on range and other non-crop lands.
- Eradicating small patches of knapweed or starthistle before they have a chance to spread.
- Containing large knapweed and starthistle infestations.
- Seeding desirable perennial grass species immediately on areas disturbed by construction, mining or other activities.
- Supporting local weed management programs.

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REFERENCES

Benefield, Carri. B., J.M. DiTomaso, G.B. Kyser, S.B. Orloff, K.R. Chruches, D.B. Marcum, and G.A. Nader. 1999. Success of mowing to control yellow starthistle depends on timing and plants branching form. California Agriculture. 53:2: 17-21.

Borman, M.M., W.C. Krueger, and D.E. Johnson. 1991. Effects of established perennial grass on yields of associated annual weeds. J. Range Manage. 44:318-26.

Bottoms, R.M. and T.D. Whitson. 1998. A systems approach for management of Russian knapweed (*Centaurea repens*). Weed Tech. 12:363-366.

Brown, E. 1914. Commercial Turkestan alfalfa seed. U.S. Dept. Agr. Bull. 138.

Brown, Melissa, C.A. Duncan, M.B. Halstvedt. 1999. Spotted knapweed management with integrated methods. Proceedings Western Soc. of Weed Sci. 52: 68-70.

Bucher, R.F. 1984. Potential spread and cost of spotted knapweed on range. Montana State University Extension Service, MontGuide 8423AG.

Chicoine, T.K., P.K. Fay, and G.A. Nielsen. 1988. Weed Science 34:57-61.

Dewey, Steven A., R.W. Mace, L.A. Buhler, and K. Andersen. 2000. The interaction of fire and herbicides in the control of squarrose knapweed. West Soc. Weed Sci. Proc. 53:8.

DiTomaso, J.M., G.B. Kyser, and M.S. Hastings. 1999. Prescribed burning for control of yellow starthistle (*Centaurea solstitialis*) and enhanced native plant diversity. Weed Science 47:233-242.

Fosse, Pat. 1998. Squarrose knapweed demonstration weed management area. National Weed Symposium. April 8-10.

Gerlach, J.D., Jr. 1997. The introduction, dynamics of geographic range expansion, and ecosystem effects of yellow starthistle. Proc. Calif. Weed Sci. Soc. 49:136-141.

Groh, H. 1940. Turkestan alfalfa as a medium of weed introduction. Sci. Agric. 20:36-43.

Groh, H. 1944. Canadian weed survey. 2nd Ann. Rep. Can. Dep. Agric. 74 p.

Harris, P. and R. Cranston. 1979. An economic evaluation of control methods for diffuse and spotted knapweed in western Canada. Can J. Plant Sci. 59: 375-382.

Howell, J.T. 1959. Distributional data on weed thistles in western North America. Leafl. West. Bot. 9:17-32.

Invaders Database, University of Montana.

Kurz, Gregg Louis. 1995. Ecological implications of Russian knapweed (*Centaurea repens* L.) infestation: Small mammal and habitat associations. M.S. thesis. Dept of Rangeland Ecology, Univ. of Wyoming. p.63.

Hirsch, Steven A and Jay A. Leitch. 1996. The impact of knapweed on Montana's economy. Ag. Econ. Report No. 355. p. 23.

Howell, J.T. 1959. Distributional data on weedy thistles in western North America. Leafl. West. Bot. 9:17-32.

Lacey, J.R., C.B. Marlow, and J.R. Lane. 1989. Influence of spotted knapweed on runoff and sediment yield. Weed Tech. 3:627-631.

Lang, R.F., J.M. Story, and G.L. Piper. 1996. Establishment of *Larinus minutus* Gyllenhal (Coleoptera: Curculionidae) for biological control of diffuse and spotted knapweed in the western United States. Pan-Pacific Entomologist. 72:209-212.

Lang, R.F., G.L. Piper, and E.M. Coombs. 1998. Establishment and redistribution of *Sphenoptera jugoslavica* Obenberger (Coleoptera: Buprestidae) for biological control of diffuse knapweed (*Centaurea diffusa* Lamarck) in the midwestern and western United States. Pan-Pacific Entomol. 74:27-31.

Lesica, Peter. 1991. The effect of the introduced weed, *Centaurea maculosa* on *Arabis fecunda*, a threatened Montana endemic. Montana Natural Heritage Program, State Library, Helena, Montana.

Maddox, D.M. 1981. Introduction, phenology, and density of yellow starthistle in coastal, inter-coastal, and Central Valley situations in California. USDA Agricultural Research Service ARR-W-20.

Panter, Kip E. 1991. Neurotoxicity of the knapweeds (*Centaurea* spp.) in horses. *In*: Noxious Range Weeds, ed. Lyn James et.al. Westview Press, Inc. pp. 316-324.

Randall, J.M. 1996. Weed control for the preservation of biological diversity. Weed Tech. 10(2):370-393.

Rees, N.E., P.C. Quimby, Jr., G.L. Piper, E.M. Coombs, C.E. Turjner, N.R. Spencer, and L.V. Knutson. 1996. Biological control of weeds in the west. Western Society of Weed Science, USDA Agric. Res. Serv., Montana Dept. of Agric., Montana State Univ.

Rice, Peter, M. D. Bendunah, C. Carlson. 1992. Plant community diversity after herbicide control of spotted knapweed. USDA FS Intermountani Res. Sta. Paper INT-460.

Rinella, Matthew J., James S Jacobs, and Roger L. Sheley. In review. Effects of season and frequency of mowing on spotted knapweed (*Centaurea maculosa Lam*.). Montana State University.

Roche, Jr., B.F., and C.J. Talbott. 1986. The collection history of *Centaurea* found in Washington State. Agric. Res. Center Res. Bull. XB0978. Washington State Univ. Coop. Ext., Pullman, WA 36pp.

Roche, B.F., Jr., and C.T. Roche. 1991. Identification, introduction, distribution, ecology, and economics of *Centaurea* species. Pages 274-291 in L.F. James, J.O. Evans, M.H. Ralphs, and R.D. Child. Eds. Noxious Range Weeds. San Francisco: Westview Press.

Sheley, R., M. Manoukian, and G. Marks. 1996. Preventing noxious weed invasion. Rangelands. 18: 100-101.

Sheley, R. L., and B.F. Roche, Jr. 1982. Rehabilitation of spotted knapweed infested rangeland in northeastern Washington. Abstr. of papers, W. Soc. Weed Sci., Denver, CO.

Sheley, R. L., B.E. Olson, and L.L. Larson. 1997. Effect of weed seed rate and grass defoliation level on diffuse knapweed. J. Range Manage. 50:39-43.

Sheley, Roger L., James S. Jacobs, and Michael F. Carpinelli.1998. Distribution, biology, and management of diffuse (*Centaurea diffusa*) and spotted knapweed (*Centaurea maculosa*). Weed Tech.12:353-362.

Sheley, Roger L., C. A. Duncan, M. B. Halstvedt, and J. S. Jacobs. 1999. Spotted knapweed and grass response to herbicide treatments. J. Range Manage. 53(2):176-182.

Story, J.M., K.W. Boggs, and R.M. Nowierski. 1989. Effect of two introduced seed head flies on spotted knapweed. Montana Ag Research 6(1):14-17.

Story, J.M., W.R. Good, L.J. White, and L. Smith. 2000. Effects of the interaction of the biocontrol agent, *Agapeta zoegana* L. (Lepidoptera: Cochylidae), and grass competition on spotted knapweed. Biological Control 17:182-190.

Story, J.M., K.W. Boggs, W.R. Good, P. Harris, and R.M. Nowierski. 1991. *Metzneria paucipunctella* Zeller (Lepidoptera: Gelechiidae), a moth introduced against spotted knapweed: its feeding strategy and impact on two introduced *Urophora* spp. (Diptera: Tephritidae). Can. Entomol. 123:1001-1007.

Thompson, Michael J. 1996. Winter foraging response of elk to spotted knapweed removal. Northwest Sci. Vol.70(1):10-19.

Trunkle, T. and P. Fay. 1991. Transportation of spotted knapweed seeds by vehicles. Proceedings, Montana Weed Control Association Annual Conference. Jan 14-16, Butte, MT. p.33.

Tyser, R.W. and C.H. Key. 1988. Spotted knapweed in natural area fescue grasslands: An ecological assessment. Northwest Sci. 62:981-987.

Wagenitz, G. 1975. Centaurea L. In P.H. Davis (ed). Flora of Turkey and the East Aegean Islands. Vol 5, Univ. Press, Edinburgh. P. 465-485.